

Producing Inverted Current-Driven Switching in Magnetic Nanopillars

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Observing current-driven switching of the magnetizations in ferromagnetic/nonmagnetic/ferromagnetic (F/N/F) metal nanopillars is an exciting development in spin-polarized transport. **Question:** Can we manipulate switching? Usually, minority electrons scatter more strongly. What happens, if we **invert** the electron scattering in both F-layers so that majority electrons scatter more strongly? Py/Cu/Py (Py = Permalloy = $\text{Ni}_{84}\text{Fe}_{16}$) has usual scattering. Fig. 1 shows magnetoresistance (MR) (dV/dI vs magnetic field H) and switching (dV/dI vs I). MR is normal—resistance (dV/dI) is lowest at large H , and switching is normal—large positive I gives step increase in dV/dI . Fe(Cr)/Cr/Fe(Cr) (Fe(Cr) = $\text{Fe}_{0.95}\text{Cr}_{0.05}$) has inverted scattering. MR is still normal, but switching is **inverted**—large positive I gives step decrease in resistance.

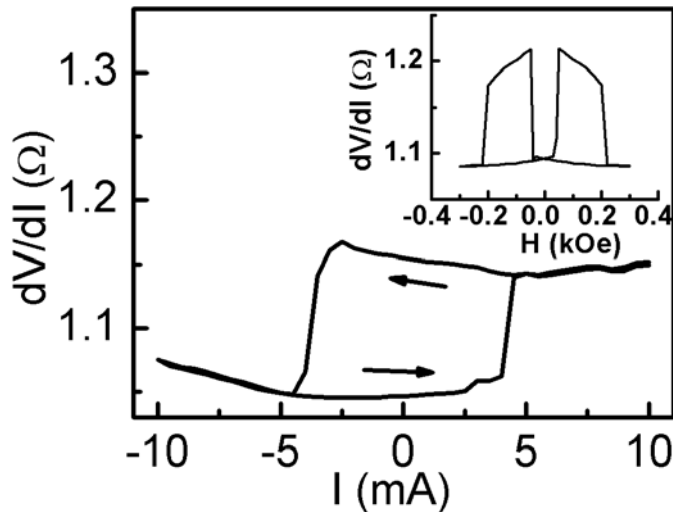


Fig. 1. Py/Cu/Py data at 4.2 K, showing normal MR in insert (dV/dI vs H at $I = 0$), and **normal** current-driven switching (dV/dI vs I at $H = 50$ Oe).

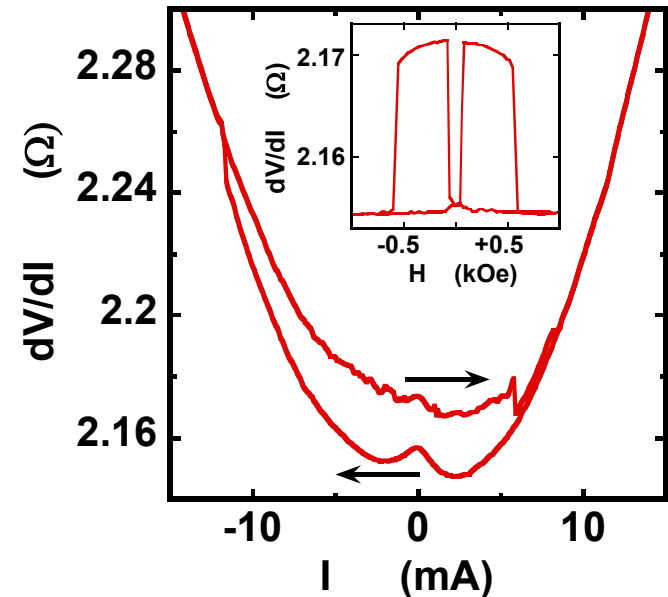


Fig. 2. Fe(Cr)/Cu/Fe(Cr) data at 4.2 K, showing normal MR in insert (dV/dI vs H at $I = 0$), and **inverted** current-driven switching (dV/dI vs I at $H = 0$).

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Technological Significance: Ferromagnetic trilayers (F/N/F) with current-flow perpendicular to the layers (CPP geometry) are under serious consideration both for next generation read heads in computer hard drives and for bits in high density magnetic random access memory (MRAM). Until recently, it was assumed that 'writing' (i.e., reversal of the magnetization of one F-layer) of a magnetic bit in such an MRAM would be done via a localized external magnetic field produced externally by an additional set of crossed wires. The new phenomenon of current-driven switching provides a potentially exciting alternative, being able to 'write' an MRAM bit simply by passing a high pulsed current through the F/N/F trilayer bit itself, with current in one direction switching the F-layer magnetization one way, and current in the other direction switching it the other way. Such a process would both eliminate the need for additional wires, and better localize the switching process.

Education: We typically supervise one Postdoctoral student, three Ph.D. students, and undergraduates and visitors. In 2003, we hosted a female French MS student, an African-American summer REU undergraduate student, and a Korean sabbatical visitor.

Outreach and Service. One of us (JB) supervised the Physics portion of the Michigan Science Olympiad from 2000 thru 2002. We gave tours of our facilities to students taking physics and chemistry classes in local high schools. We participated in a daylong Sensors Program during Science Day at the Mall. JB is now co-chair of the physics panel for the NRC fellowship program evaluating candidates for postdoctoral fellowships for federal laboratories, and was just elected Vice-President of GMAG, the Magnetism Group of the APS. Next year he will become President Elect, the following year President, and finally, Past President during his four year commitment. WPP has been a member of the advisory board of the Magnetism and Magnetic Materials conference since 1998.



Jack Bass and William Pratt at Science Day at the Mall